

**Appendix A**

**Sage Earth Science Report**

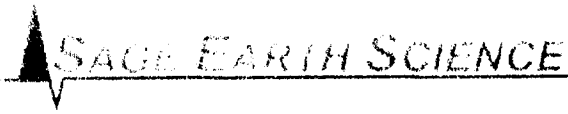


## **Appendix A**

### **Sage Earth Science Report**

Two surface geophysical studies were performed by Sage Earth Science at the Subsurface Disposal Area (SDA) within the Idaho National Laboratory Radioactive Waste Management Complex from FY 2003 through 2004. These studies were conducted to support analysis of remedial alternatives and future environmental restoration needs for the SDA, with the exception of Pit 9 and the low-level waste pit. The FY 2004 survey produced comprehensive, high-resolution geophysical data for most of the SDA. The Sage Earth Science report for this survey comprises this appendix.





May 24, 2004

BBWI  
P.O. Box 1625  
Idaho Falls, ID 83415

**RE: DATA DELIVERY / FINAL REPORT  
GEOPHYSICAL LAND SURVEY OF SDA AT RWMC  
SUBCONTRACT NO. 00029560**

## **INTRODUCTION**

Locating buried objects including drums, underground storage tanks, and other waste is among the most popular applications of geophysics in the environmental industry. Basic questions relating to the location and distribution objects, pits, and trenches can be addressed in a straightforward manner with confident results. Most often, magnetic field and/or electromagnetic induction surveys are performed depending on the project objective and site conditions. Over the period of March 8 thru April 29, 2004 magnetic field and time domain electromagnetic induction (TDEMI) surveys were performed at the Subsurface Disposal Area (SDA) of the Radioactive Waste Management Complex (RWMC) located at the Idaho National Engineering and Environmental Laboratory (INEEL). Included in this report are the results of the geophysical surveys covering the approximate 80-acre landfill site.

## **TECHNICAL APPROACH**

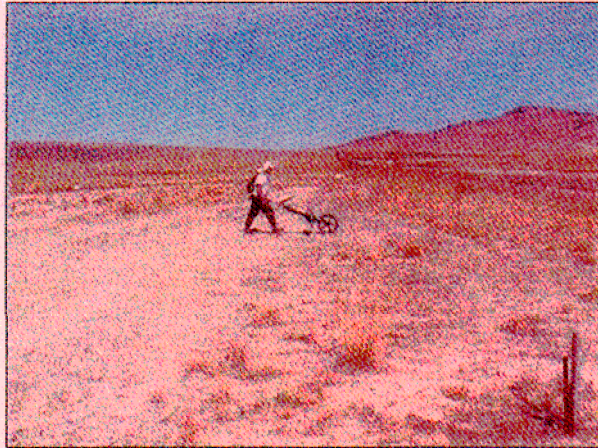
Given project needs and site conditions, proposals to conduct high-resolution metal detection surveys were sought. To meet these objectives, magnetic field and TDEMI surveys were proposed. Of critical importance in the design of a geophysical survey is the selection of the appropriate survey method, data station, and profile spacing. Typically, the data spacing is based on a number of factors including:

1. target size
2. the degree which it is necessary to place a location or boundary
3. the degree which it is necessary to distinguish between closely spaced boundaries or individual objects
4. interference from small scattered surface or near surface objects
5. interference from surface features (e.g. fences, buildings, utilities, wells, posts etc.)
6. requirements for size/depth estimates
7. properties of the measurement equipment

Based on these parameters, the magnetic field data were collected on a 6-inch by 20-inch station/profile spacing. The TDEMI data were collected on an 8-inch by 40-inch station/profile spacing.

### *Magnetics Field Measurements*

Magnetic objects such as steel drums, rebar, underground storage tanks, and other ferrous/magnetic objects produce localized variations in the earth's magnetic field. By mapping those variations, the location, size, and depth of magnetic objects can be determined. In typical burial settings, mapping the distribution of magnetic objects will clearly delineate the location of fill areas, pits, and trenches



The magnetic field data for this task were acquired using the Rapid Geophysical Surveyor (RGS), a proprietary magnetic field mapping system jointly developed by Sage Earth Science and the INEEL. Using high precision fluxgate gradiometers, vertical gradient of the vertical magnetic field data were collected on a 6-inch by 20-inch station/profile spacing (50,000 points/acre) over the approximate 80-acre site totaling nearly 4 million data points.

The RGS employs two fluxgate magnetic gradient sensors spaced 20 inches apart; therefore collecting two data profiles simultaneously during each pass of the mapping system across the site. An optical encoder integrated with the system wheel drives the data acquisition. The wheel and encoder serve as an odometer to located each data point along profile. Data profiles were positioned by referencing a 200-foot by 200-foot control grid placed at the site by the INEEL. Each profile is located by placing a visual marker at end of each 200-foot pass. The visual marker is used to guide the operator in a straight line across each 200-foot grid cell.

A fluxgate magnetometer consists of a "sensing" coil surrounding an inner "drive" coil that is wound around a ring-shaped core material. An alternating current is applied to the drive coil that induces a current in the sensing coil. Without an external magnetic field, the total flux seen by the sensing coil is zero. When an external magnetic field is present, the flux is switched to saturation. The voltage induced in the sensing coil is proportional to the rate of change of the flux with respect to time. Because of the effect of the external magnetic field on the changing magnetic permeability of the core, the voltage induced in the sensing coil contains even harmonics of the drive current frequency. The strength of the induced harmonics is proportional to the strength of the external magnetic field.

The Billingsley Magnetics GRAD-12 sensor used in the RGS is a single axis fluxgate gradiometer. The sensor consists of two single axis magnetometers spaced 12 inches apart along a common vertical axis. Each magnetometer provides an analog output corresponding to the component of the magnetic field along its axis. The gradient is derived by measuring and

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logging the difference between the two closely spaced magnetometers. The property measured is therefore the vertical gradient of the vertical magnetic field reported in nanoTesla per meter.

#### *Time Domain Electromagnetic Induction Survey (Geonics EM-61)*

Electrically conductive objects such as steel drums, rebar, underground storage tanks, and other metallic objects can be located by inducing electrical currents into the subsurface and measuring the response at the surface. By mapping this response, the location, size, and depth of conductive objects can be determined. In typical burial settings, mapping the distribution of metallic objects will clearly delineate the location of fill areas, pits, and trenches



The TDEMI response data were acquired using a Geonics EM-61 metal detector. The EM-61 is a high sensitivity, high-resolution time-domain metal detector. The system consists of a transmitter coil that generates a pulsed primary magnetic field, which induces eddy currents in nearby metallic objects. Two separate receiver coils mounted on a trailer assembly measure the decay of the induced current. The response curve is a single well defined positive peak centered over the conductive body facilitating an accurate location and

from which a depth can be estimated based on the width of the anomaly or the relative response of the two receiver coils.

The upper coil and lower coil, response data were recorded on an 8-inch by 40-inch station/profile spacing (20,000 points/acre) over the 80-acre site totaling an approximate 1.4 million data points. An optical encoder integrated with the system wheel drives the data acquisition. The encoder and wheel serve as an odometer to locate each data point along profile. Data profiles were positioned by referencing a 200-foot by 200-foot control grid place at the site by the INEEL. Each profile was located by placing a visual marker at the end point of each 200-foot pass. The visual markers were used to guide the operator in a straight line across each grid cell. The logged responses are reported in millivolts.

#### **TECHNICAL REQUIREMENTS**

All data were acquired in accordance with INEEL TTP 154 and Sage Earth Science Standard Operating Procedures 3.1 *Magnetic Field Mapping (RGS)* or 4.3 *Time Domain Electromagnetic Induction*.

All locations are provided in State Plane, Idaho East Zone (1101), U.S. Survey Feet, horizon datum NAD27. The data were acquired on the dates between March 8, 2004 and April 29, 2004. Depth estimates derived from this data should be reference to the ground surface elevation between those dates.

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## DATA PRESENTATION

The following figures show the results of each survey: vertical gradient of the magnetic field in nanoTesla per meter and EM-61 bottom coil response in millivolts each in State Plane, Idaho East Zone (1101), U.S. Survey Feet, horizontal datum NAD27.

### *Magnetic field map*

For the purposes of interpretation, every magnetic object can be considered to be a small bar magnet with both a north and south pole. These areas are represented as an area of positive gradient (reds/purples) and negative gradient (blues/greens). Low field areas are represented with yellow.

The character of a magnetic anomaly is related to the magnetic properties of the object as well as its size and depth of burial. In general, a large object or groups of magnetic objects will produce a high amplitude field. However, the amplitude as measured at the surface, is strongly influenced by distance to the object or its depth of burial. The way in which the amplitude changes laterally or as the system passes over a buried object is related to the depth of burial.

Those pits that are populated with high volumes of ferrous metal are well expressed; in particular pits 1-6, 8, 10, 13, 14, and 15. Pits 11, 12, and acid pit are poorly expressed in the magnetic field data.

A number of the trenches and soil vault rows are well expressed. In general, the rows and trenches on the west end of the SDA are more clearly expressed due the contents of the trench and the depth of burial. Many of trenches and rows are not well expressed most likely due to the nature of the material received in those trenches. These areas will require an extensive interpretation effort to delineate or could be handled on a case-by-case basis as project needs arise.

### *TDEMI Map*

For the purposes of interpretation, every electrically conductive object will produce a single well defined positive peak centered over the conductive body facilitating an accurate location and from which a depth can be estimated based on the width of the anomaly or the relative response of the two receiver coils.

The amplitude of a TDEMI anomaly is related to the surface area of the metallic object as well as its depth of burial. In general, a large object or groups of metallic objects will produce a high amplitude response. However, the amplitude as measured at the surface, is strongly influenced by the distance to the object or its depth of burial. Therefore, the way in which the amplitude changes laterally is closely related to the depth of burial of the object. Similarly, because of the influence of distance, the difference in response between the upper and lower coil is related to the depth of burial.

Those pits that are populated with high volumes of metal are well expressed; in particular pits 1-6, 8, 10, 13, 14, and 15. Pits 11, 12, and acid pit are poorly expressed in the TDEMI data.

*Figure 1. Magnetic field map showing the results of the magnetic field survey. The map displays the vertical gradient of the magnetic field in nanoTesla per meter. The map shows a large area of positive gradient (red/purple) in the center, indicating a high magnetic field, and a large area of negative gradient (blue/green) on the right side, indicating a low magnetic field. The map also shows a yellow area in the bottom left corner, representing low field areas.*

A number of the trenches and soil vault rows are well expressed. In general, the rows and trenches on the west end of the SDA are more clearly expressed due to the contents of the trench. Many of trenches and rows are not well expressed likely due to the nature of the material received in those trenches. These areas will require an extensive interpretation effort to delineate or could be handled on a case-by-case basis as project needs arise.

## DATA PROCESSING SEQUENCE

The following data processing steps were applied to each of the data sets.

### TDEMI data

1. Transformation of field/local grid coordinates to State Plane, Idaho East Zone (1101), U.S. Survey Feet, horizontal datum NAD27.
2. Inline spline fit to establish regularly spaced inline data
3. line by line leveling (instrument drift correction)
4. Instrument Lag correction - 2 fiducials
5. (X,Y,Z1,Z2) ASCII output (easting, northing, top coil, bottom coil)
6. 3.28 ft by 3.28 ft gridding - minimum curvature algorithm - for report graphics
7. 0.5 ft by 0.5 ft gridding - minimum curvature algorithm - for INEEL GIS

### Magnetic field data

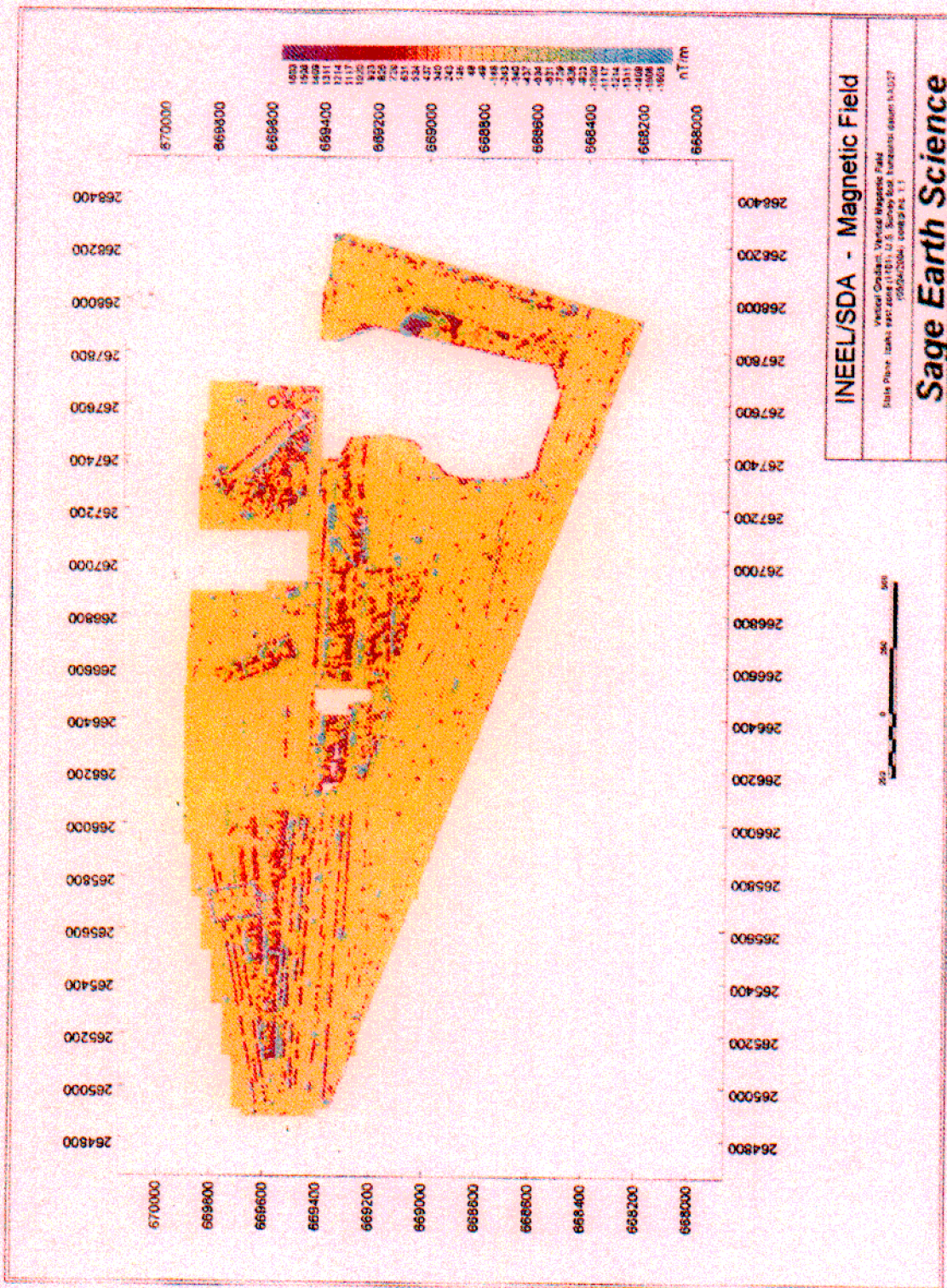
1. Transformation of field/local grid coordinates to State Plane, Idaho East Zone (1101), U.S. Survey Feet, horizontal datum NAD27.
2. Inline spline fit to establish regularly spaced inline data
3. line by line leveling (instrument drift and magnetometer orientation correction)
4. (X,Y,Z1) ASCII output (easting, northing, magnetic gradient)
5. 3.28 ft by 3.28 ft gridding - minimum curvature algorithm - for report graphics
6. 0.5 ft by 0.5 ft gridding - minimum curvature algorithm - for INEEL GIS

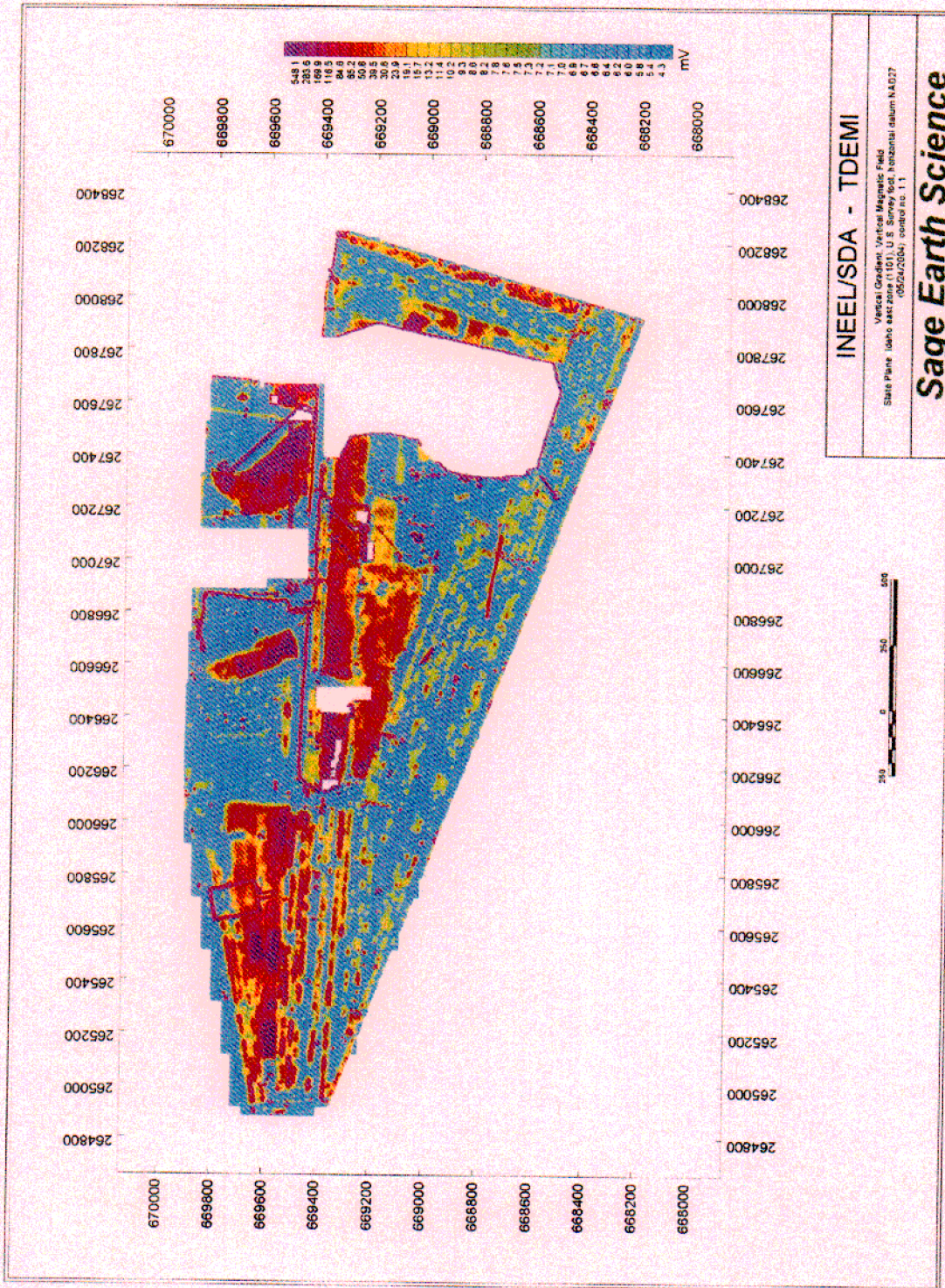
## DIGITAL DATA FORMATS

The full geophysical data sets are included on the accompanying compact data disk. The data have been provided in two formats, ASCII (x,y,z) and ARCVIEW raster grid for inclusion into the INEEL GIS data system.

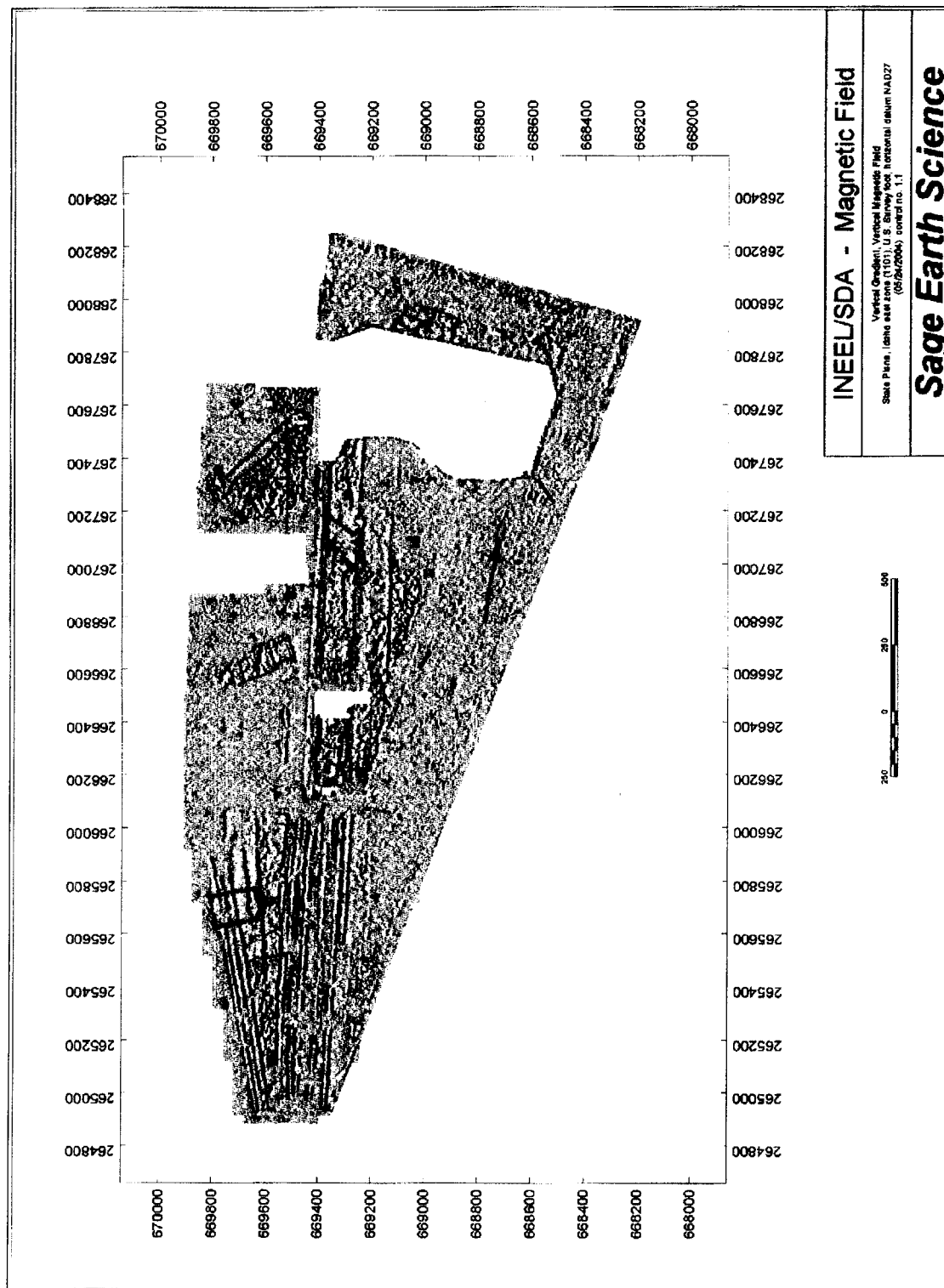
EM_BOTTOM_COIL.flr	89,947 KB	ARCVIEW FLT File	Raster grid
EM_BOTTOM_COIL.flr	4 KB	ARCVIEW GI File	Registration file
EM_BOTTOM_COIL.hdr	1 KB	ARCVIEW HDR File	Header file
EM_TOP_COIL.flr	89,947 KB	ARCVIEW FLT File	Raster grid
EM_TOP_COIL.flr	4 KB	ARCVIEW GI File	Registration file
EM_TOP_COIL.hdr	1 KB	ARCVIEW HDR File	Header file
Sda-em-out	52,511 KB	ASCII (X,Y,Top,Bottom)	ASCII data file
Sda-mag.flr	90,331 KB	ARCVIEW FLT File	Raster grid
Sda-mag.flr	4 KB	ARCVIEW GI File	Registration file
Sda-mag.hdr	1 KB	ARCVIEW HDR File	Header file
Sda-mag-out	106,313 KB	ASCII (X,Y,Mag gradient)	ASCII data file

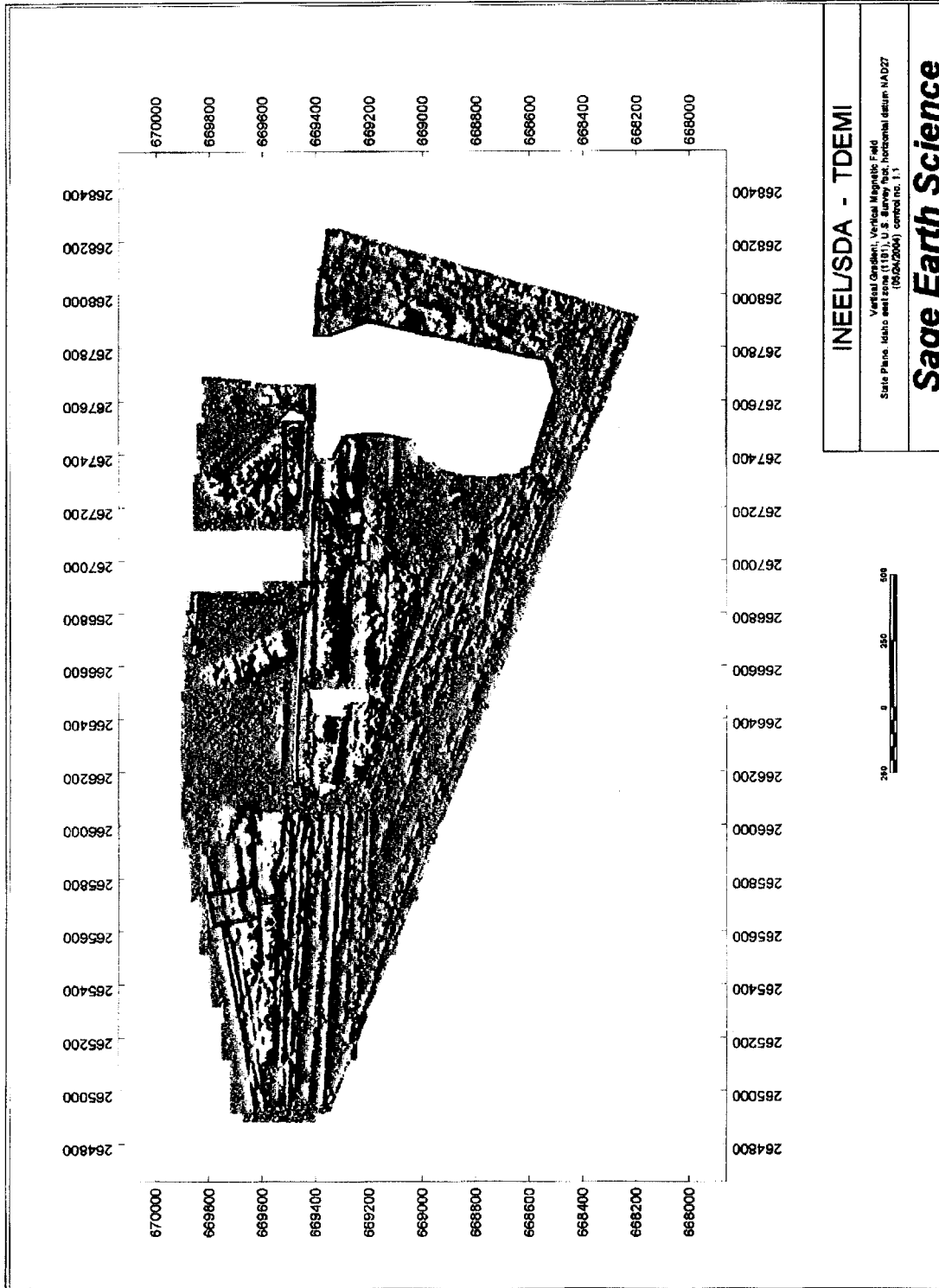
Appendix A  
Geophysical Survey Maps  
(color contour)





Appendix B  
Geophysical Survey Maps  
(shaded relief)





Appendix C  
Geophysical Survey Maps  
(combination color contour/shaded relief maps)



